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Nano-biophotonics explored by Light Robotics

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The 2014 Nobel Prize in Chemistry celebrated the invention of so-called 'optical nanoscopy' - a highly advanced nanoscale light-based microscopy modality that can surpass the classical far-field diffraction limit and provide optical resolutions down to a few nanometers. Associated with this breakthrough is the rapidly emerging field of light-based 3D printing based on powerful approaches offered by e.g. nonlinear photo-polymerizations. Currently, it is possible to 3D laser-print nanoscopic structures with voxel resolutions down to a few tens of nanometers. By adding a third key scientific accomplishment - namely the fascinating ability of focused light to capture, trap and manipulate tiny objects - one can approach a triangulation of new functionalities required for true light-driven nano-robotics. By integrating all these amazing optics and photonics breakthroughs we can create the conditions for harnessing most of the functionalities required to develop the fascinating concept of true so-called Light Robotics.

We foresee that it will soon become possible to equip 3D laser-printed robotic micro-structures with multi-functional biophotonics nanoprobes or nanotips fabricated with true nanoscopic resolution. The uniqueness of such an approach is that even if a micro-biologist aims at exploring e.g. cell biology at nanoscopic scales, the main support of each laser-robotic structure can be 3D printed to have a size and shape that allows convenient laser manipulation in full 3D – even using relatively modest numerical aperture optics. An optical robot is typically equipped with a number of 3D printed "track-balls" that allow for real-time 3D light manipulation with six-degrees-of-freedom. This creates a drone-like functionality where each light-driven robot can be e.g. joystick-controlled and provide the user a feeling of stretching his/her hands directly into and interacting with the biologic micro-environment. The light-guided robots can thus act as free-floating probes to monitor micro-biologic processes and provide spatially targeted mechanical, chemical or even optical stimuli that would otherwise be impossible to achieve in a full 3D biologic environment.

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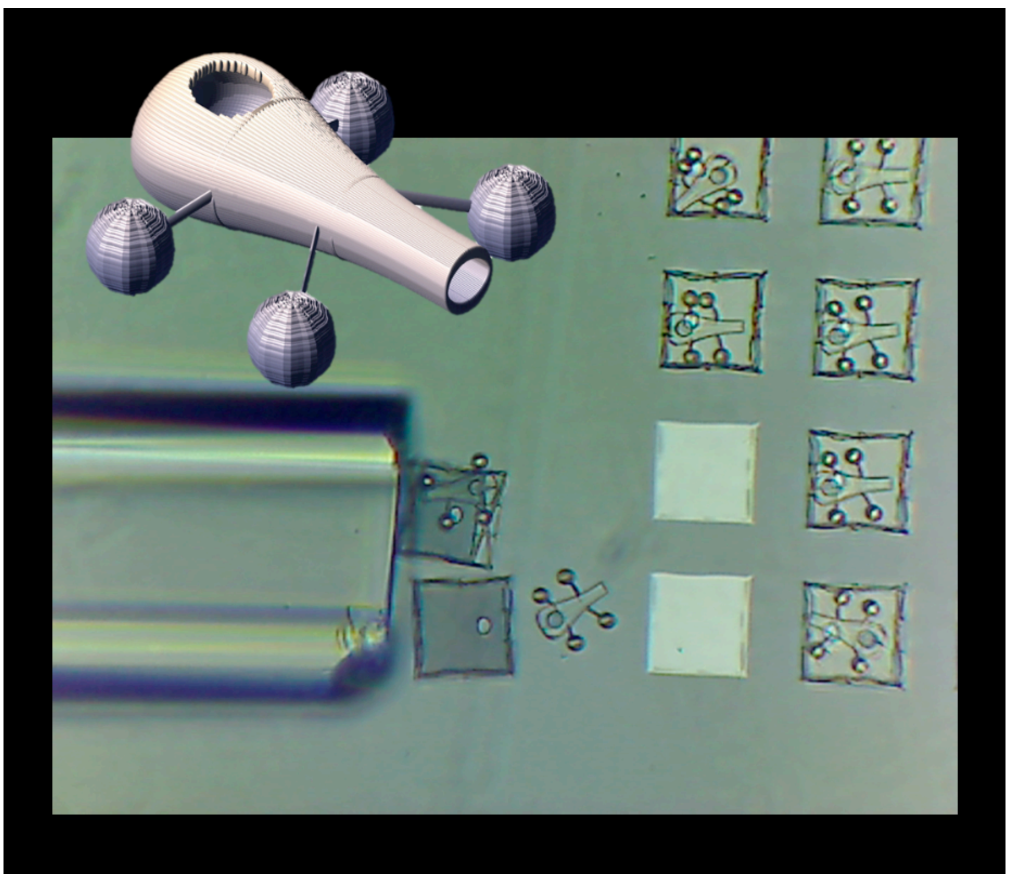

Fig. 1: The latest generation of our syringe-equipped light-driven micro-robotics. Adapted from ref. NPG-LSA 2016.